Review

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# The Impact of Climate Change on Chronic Kidney Disease

## İklim Değişikliğinin Kronik Böbrek Hastalığı Üzerindeki Etkisi

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**ABSTRACT**

Climate change problems like air pollution and global warming are assumed to be related to human activity. Global warming and air pollution are related issues. The state of health is assumed to be negatively impacted by these climatic changes, particularly in terms of the incidence and progression of chronic kidney disease. The aim of this review is to update physicians on how air pollution and global warming affect kidney disease.

**Keywords:** Climate change, chronic kidney disease, heat stroke, particulate matter

**ÖZ**

Hava kirliliği ve küresel ısınma gibi iklim değişikliği sorunlarının insan faaliyetleriyle ilgili olduğu varsayılmaktadır. Küresel ısınma ve hava kirliliği birbiriyle ilişkili konulardır. Sağlık durumunun, özellikle kronik böbrek hastalığı insidansı ve ilerlemesi açısından, bu iklim değişikliklerinden olumsuz etkilendiği varsayılmaktadır. Bu derlemenin amacı, hekimleri hava kirliliği ve küresel ısınmanın böbrek hastalığını nasıl etkilediği konusunda güncellemektir.

**Anahtar Sözcükler:** İklim değişikliği, kronik böbrek hastalığı, sıcak çarpması, partikül madde

## Introduction

One of the biggest hazards to human health in the twenty-first century is climate warming, which is responsible for 12.6 million deaths in the world (1). Both kidney illness and climate change get worse over time. Those who repeatedly or extensively undergo dehydration insults from extreme heat are more likely to suffer from acute or chronic kidney problems. Particle pollution, a primary result of burning fossil fuels, may also be largely responsible for the prevalence of chronic kidney disease (CKD) and CKD-related pathology (2).

The UN Framework Convention on Climate Change defines climate change as a change of climate that is related directly or indirectly to human activity that modifies the composition of the global atmosphere in addition to natural climate variability (3). Climate change poses a dilemma that imperils the continuation of life as we know it on Earth. Recognizably, according to the Intergovernmental Panel on Climate Change (IPCC), human activity has caused climate warming at an unusual tempo in the last 2000 years (4). If emissions continue at their current rate, the IPCC estimates that globally the temperatures will rise by 2-3.5 degrees Celsius by the end of the century (4).

The effects of climate change are particularly harmful to kidney health because environmental issues make kidney diseases worse. However, dialysis therapy has a significant environmental impact due to a variety of aspects, including energy and water use, greenhouse gas emissions, and waste production (5).

Despite numerous international climate agreements, the world's reactions are woefully insufficient, and the nephrological community's involvement appears to be lacking (5).

### Climate Change-Related Kidney Disorders

People with kidney illness are more vulnerable to the direct health effects of climate change as well as to disruptions in the healthcare system during natural disasters, which exacerbates the variety of negative effects of climate warming (6). Climate change effects like heat exposure and volume depletion are risk factors for nephrolithiasis, acute kidney injury (AKI) as well as CKD in South America and abroad (Mesoamerican nephropathy) (7).

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Low air quality has a negative impact on the progression of CKD. In addition, due to climate warming, changes in the landscape caused by precipitation, and human behavior that increases vector-human contact, vector-borne diseases continue to be major causes of kidney disease in low-income nations and are spreading throughout the world (8).

**Heat stress as a cause of kidney disorders**

In recent studies, CKD epidemics have been reported in several high-temperature places of the world, mainly affecting individuals who perform physical work in sweltering temperatures. (9) The disease is more prevalent in Central America's hotter regions due to heat stress (10), which has given rise to the theory that kidney disorders may be caused by global warming (11). In fact, a study revealed that working in sugarcane fields was linked to higher humidity since there were cane present and El Nino events (12). Also, several studies in South America have shown that repeated AKI from heatstroke is increasing the incidence of CKD in sugarcane workers (13-15). The majority of cases show no symptoms, but some patients exhibit fever, leukocytosis, leukocyturia, and AKI, which may necessitate hospitalization (16).

Increased body temperatures, the activation of the polyol-fructokinase pathway by hyperosmolarity, and the long-term effects of vasopressin on tubular and glomerular injury are probably the mechanism of AKI (17). Also, according to different studies, heat, volume depletion, and increased uric acid serum levels due to exercise-induced rhabdomyolysis result in concentrated and acidic urine, which can cause tubular injury, nephrolithiasis, and urinary tract infection (18-20). Rehydrating with soft drinks also carries the risk of AKI because they contain fructose, which when metabolized by the kidneys causes tubular damage, inflammation, and oxidative stress (21).

Heat stress nephropathy is now being documented worldwide, especially in hot agricultural communities, which is concerning since it can lead to an epidemic of CKD (22,23).

**Vector-Borne Diseases and Kidney**

In warm areas, acute febrile infections from vector-borne diseases are a major contributor to AKI. The most frequent diseases that occur in warmer climates are caused by the zika virus, malaria, and dengue. Mosquitoes, especially female ones, which are mostly to blame for vector-borne diseases, eat more often and lay more eggs in warmer climates (24). The mortality rate for patients with malaria increases by 45% when AKI is present (25). Even though the information on AKI caused by dengue is scarcer and more inconsistent, rates that have been documented in patients who have needed hospitalization are relatively high, with fatality rates of 9% to 25% (26). Another mosquito-borne virus, Zika, may become more dangerous to people as a result of climate warming. Often asymptomatic or resulting in a mild febrile viral disease, the infection can result in fetus malformation, such as microcephaly (27). Travelers with immunosuppressed conditions, such as those with kidney disease or who are receiving dialysis, and transplant patients have recently been warned to take vigilance (27).

**Particulate Matters and Kidney**

One of the main contributors to the burden of diseases worldwide is considered to be air pollution (28). The principal component of air pollution that has the greatest detrimental impact on human health is particulate matter (PM), which predominantly consists of solid particles produced during the combustion of coal, gasoline, and diesel fuels (29). Other elements of environmental air pollution may include differently sized particulates (e.g., $PM_{2.5}$, which has a diameter of 2.5 μm, and $PM_{2.5-10}$), gaseous pollutants (e.g., nitrogen dioxide, carbon monoxide, sulphur dioxide, and ozone), and heavy metals (cadmium, lead, and mercury) (30).

It is commonly assumed that particulate matter, especially $PM_{2.5}$, has a negative impact on the onset and progression of cardiovascular disease due to the high risk of vascular dysfunction, like inflammation and atherosclerosis (31,32). The kidney, which is composed of arteries and arterioles, may potentially be vulnerable to PM-related atherosclerosis (31). A new risk factor for CKD that is getting increasing attention currently is air pollution (33), which is in addition to traditional risk factors for the development of kidney diseases such as hypertension, diabetes, ethnicity, age, smoking, episodes of AKI, use of analgesic drugs, and genetic factors (34,35). In a local cohort study where 669 older men were conducted, Mehta et al. (36) discovered that every 2.1 $\mu g/m^3$ increase in $PM_{2.5}$ exposure was linked to a 1.87 mL/min/1.73 $m^2$ decrease in eGFR and an additional yearly impairment in kidney function of 0.60 mL/min/1.73 $m^2$. According to a different study by Xu et al. (37), membranous nephropathy risk was elevated by prolonged exposure to high $PM_{2.5}$ concentrations. According to a cohort study, conducted on more than 2 million US veterans without a history of kidney disease, chronic exposure to PM and gaseous pollutants is linked to an elevated risk of new-onset and progression of CKD, and development of kidney failure which requires renal replacement therapy (34). The risk is increased by 26-28% for every 10 $\mu g/m^3$ rise in $PM_{2.5}$ concentration (34).

**Arsenic**

The occurrence of kidney damage and the start of hypertension may both be influenced by exposure to arsenic (As) in the environment, at work, and in an individual's diet (38,39). A study conducted in Taiwan showed a significant relationship between urinary As and the incidence of CKD. It was shown that high levels of urine As quadrupled the chance of developing CKD (40). Acute As exposure to the kidney can cause hypercalciuria, albuminuria, nephrocalcinosis, and necrosis of the kidney papillae, as well as tubulointerstitial nephritis and acute tubular necrosis (41,42).

**Cadmium**

Another common nephrotoxic environmental contaminant is cadmium (Cd). Diet and smoking are the main sources of Cd exposure. Since Cd directly damages the kidneys, it can result in polyuria, tubular damage, Fanconi syndrome, as well as progressive reduction of eGFR (43). The idea that chronic

Cd exposure is thought to hasten the progressive reduction of eGFR is supported by a variety of experimental research (44,45). Proteinuria is the most common complication (46). Megalin and cubilin, which promote the endocytosis of filtered proteins along the proximal tubule, have been linked to proteinuria (47,48). The prevalence of kidney stones also rises in people who are persistently exposed to or receive higher doses of Cd, probably as a result of the elevated calcium concentration in urine (38).

**Lead**

The primary effects of lead (Pb) exposure on kidney cells are inflammation and mitochondrial oxidative stress (38). Exposure to low levels of Pb results in glomerular hypertrophy (38). Fanconi syndrome is caused by acute Pb exposure and tubulointerstitial nephritis from long-term Pb exposure (49). Different studies conducted in different countries showed a positive correlation between Pd exposure and serum creatinine concentration (50,51).

**Mercury**

Mercury (Hg) has also been linked to the development of CKD (52). Endoplasmic reticulum dilatation, transformed mitochondrial structure, and nuclear pyknosis are all results of short-term exposure (53). Microvilli start to disappear after 12 hours, and cell death is accompanied by rupture of the plasma membrane and cell separation from the basement membrane (54). Glomerular damage can also result from long-term exposure to Hg substances (38). A study that included 272 participants with CKD and 272 controls who were matched for age, sex, and area revealed that exposure to Hg was independently linked to a higher probability of developing CKD (55).

**Tobacco**

Another air contaminant that is hazardous to kidneys is tobacco. There are various theories that explain various mechanisms related to CKD. In healthy persons, smoking has been linked to microalbuminuria and idiopathic nodular glomerulosclerosis, and in those with CKD, especially with diabetic nephropathy (DN), it has been linked to more heavy proteinuria (56,57). In a study where 926 cases of CKD and 998 controls participated, an association between smoking and glomerulonephritis and nephrosclerosis was discovered (58). Smoking accelerated the development of DN and nephroangiosclerosis (58,59). Endothelial dysfunction, intimal hyperplasia, and atherosclerosis of small and large vessels are all effects of tobacco (57). Ingredients in tobacco cause glomerulosclerosis, tubulointerstitial fibrosis, and mesangial proliferation in the kidney (60). Particularly, nicotine increases the formation of extracellular matrix in human mesangial cells (61) and acrolein causes kidney cell apoptosis and the generation of reactive oxygen species (ROS) (62). Another component of tobacco that negatively affects CKD is Cd. Smokers' serum Cd concentrations are 4- to 5-times greater than non-smokers', and their kidney Cd concentrations are 2- to 3-times higher (63).

An experimental study suggested that mechanisms for smoking-induced kidney injury included increased sympathetic activity which led to hypertension and increased intraglomerular capillary pressure (64). It was shown that the incidence of kidney function loss was greater in current smokers than in non-smokers (65).

In addition to these results, cigarette use has also been linked to proteinuria in people with and without CKD (66-68). Proteinuria was discovered in 4.6% of current smokers and 1.5% of non-smokers among a population selected from a chemical factory in Japan (68). In a meta-analysis among smokers with type 1 DM or type 2 DM compared to non-smokers, the incidence rate of DN was greater (69). Also, the study indicated that smoking posed the greatest risk for macroalbuminuria, most likely over a long period of time (69). To assess smoking exposure, measurements of the nicotine metabolite cotinine and creatinine levels in serum, as well as the albumin/creatinine ratio were evaluated in a study conducted in Turkey (70). Serum cotinine concentrations and the urinary albumin-creatinine ratio were both greater in current and passive smokers than in controls, although creatinine blood concentrations were higher in current smokers (70).

**Traffic air pollution**

Another type of air pollution is that caused by traffic. In a study in Taipei city, the authors came to the conclusion that 1-year exposures to air pollution from traffic, especially to $PM_{2,5}$ and $PM_{10}$, were linked to lower eGFR, a higher prevalence, and incidence of CKD (71). In another study conducted in Runcorn, UK, the author found that compared to a control population residing distant from industrial facilities, those who lived close to industrial facilities had an increased mortality rate from CKD (72).

**The effect of kidney disease on the environment**

The medical industry has a significant environmental impact because of the amount of water and energy used in manufacturing, interventions, and waste production (73). Nature is in danger due to the pharmaceutical sector's large-scale emissions of greenhouse gases and pollutants (74). Non-etheless, dialysis involves a heavier strain compared to other therapeutic modalities. There is no doubt that producing plastic, which is a crucial element of dialyzers and dialysis equipment, needs a significant quantity of chemicals, energy, and water (75). Moreover, each dialysis session uses large amounts of drinkable water, including reverse osmosis water and dialysate generation (75). With a lot of such units around the world, the typical unit's water use can easily reach one million liters per year (75). Numerous factors contribute to the extensive production of greenhouse gases and pollutants, including the manufacturing of filters, machines, and other consumables, dialysate production and heating, monitoring, lighting, and climatization of the unit, as well as the transport of materials and patients (76,77). Discarding auxiliary resources increases the waste problem even more (gloves, protective clothing, food packages, and drinking cups for meals provided during dialysis, drug wrappings, and containers) (78). However, there is no data comparing the overall ecological burden of peritoneal dialysis and hemodialysis (HD) techniques. According to one investigation, transplanting had a better environmental impact compared to dialysis modalities (79). Although home dialysis is frequently thought of as being more environmentally than other modalities due to the lower water consumption of the treatment, this is likely largely countered by the water and energy required to create a large number of plastic dialysate bags, dialysate, and transport those bags (77,79).

## Conclusion

In conclusion, climate change has a big impact on people's health. Dehydration, elevated serum uric acid levels, and hyperosmolarity induced by heat stroke can result in AKI, which can eventually result in CKD. Due to the dysregulation of renal hemodynamics, oxidative stress, and inflammatory response, air pollution, an increased level of varied-size PM and heavy metals may also result in AKI. People need to be educated about maintaining a low-carbon lifestyle and stopping smoking.

### Ethics

**Peer-review:** Externally peer reviewed.

### Authorship Contributions

Concept: L.S., R.K., Design: L.S., R.K., Data Collection or Processing: L.S., R.K., Analysis or Interpretation: L.S., R.K., Literature Search: L.S., R.K., Writing: L.S., R.K.

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